A Unified View of Research Needs for the Columbia River, Estuary and Plume

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With thanks to Philip Orton

Roadmap to Talk –

- My research program
- What biophysical problems do we need to solve?
- How can we solve them? – some preliminary ideas

Overall message: we need to understand the CR system as an integrated whole, to deal with pressing management issues

My research program – a quick overview

The Hydrodynamic Processes & Ecosystems Group at OGI/OH&SU –

- Overall mission – understanding the role of fluid mechanics in coastal ecosystems
- Areas of expertise –
  - Estuarine circulation and salinity intrusion
  - Tides and tidal analysis
  - Turbulence, mixing, small-scale fluid mechanics
  - Sediment transport and measurement methods
  - CR hydrology, climate and sediment supply
  - Ecosystem analysis – looking at the big picture

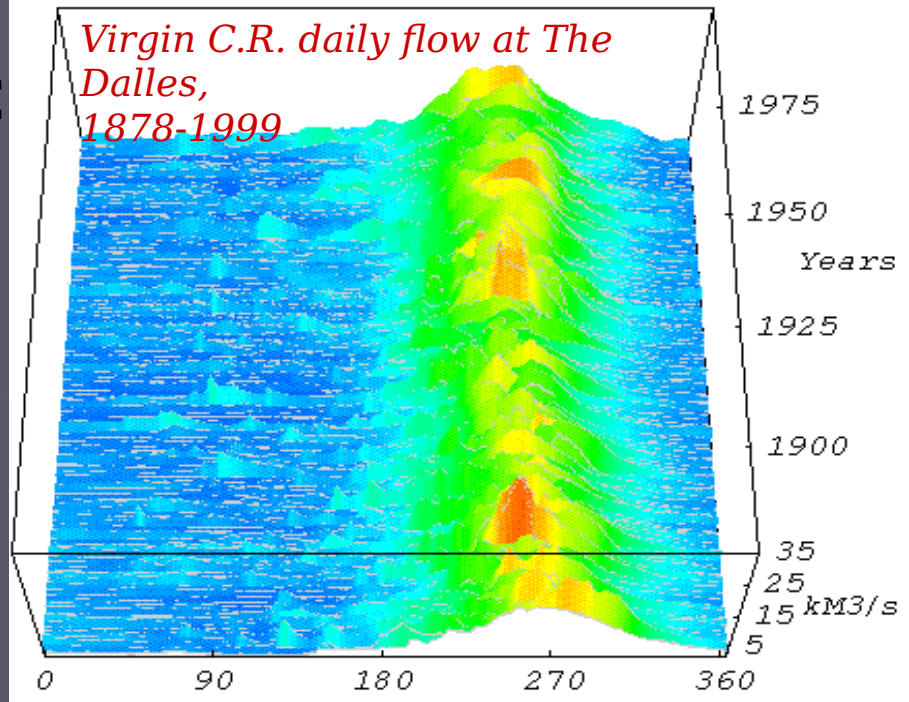
Research Programs –

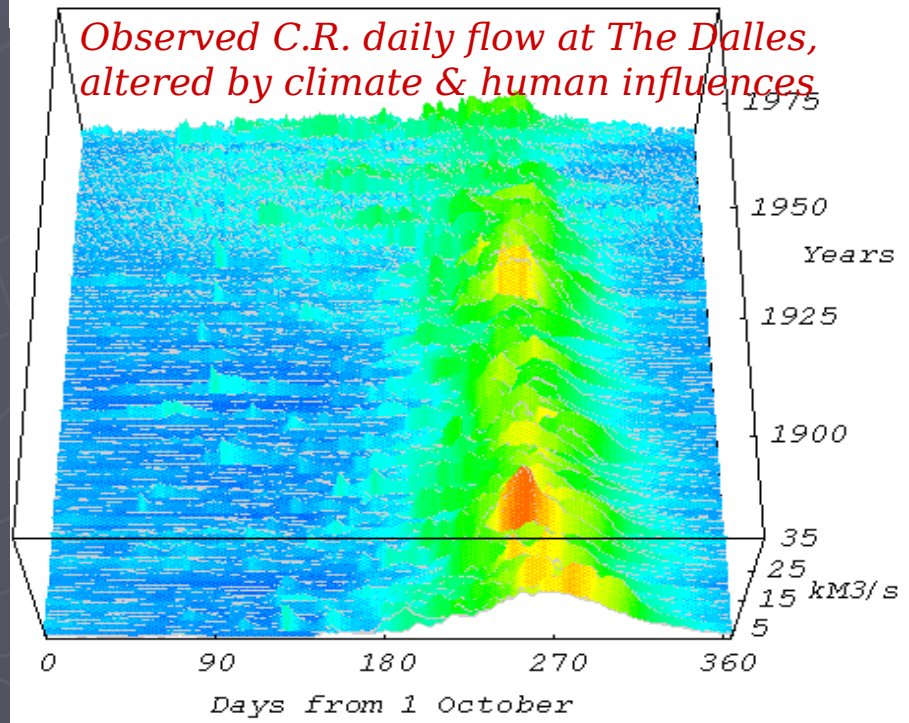
- National Science Foundation (NSF) –
  - CR plume biophysics study (RISE) – background for mgt needs
  - Estuarine sediment trapping/export, and transport methods – to understand sediment retention, export to coast
- BPA-funded programs for assessment of hydropower system impacts on juvenile salmonids below Bonneville Dam –
  - NOAA-Fisheries estuary study (starts 2003)
  - NOAA-Fisheries plume study (ongoing)
  - *Optimization of FCRPS Impacts on Juvenile Salmonids* (starts 2004)
- NOAA-NESDIS plume remote sensing (2002-2003)
- Corps of Engineers and NOAA-Fisheries estuary study –
  - Analyses of changes in riverine salmon habitat
  - Define the character of suspended sediment supplied to estuary

Changes in CR Hydrology: Flow –

- Average flow down 15% since 1900; irrigation +evaporation: 8%, climate change: 7%
- Peak flows down ~45%, mostly hydropower, flood control
- Impacts on estuary and plume:
  - Increased estuarine salinity intrusion, decreased salmon habitat
  - Decreased turbidity in spring, less annual estuarine productivity(?)
  - Plume smaller, earlier; altered interaction with coastal upwelling
  - Changes in timing, form and amount of iron input

"Virgin flow" is the flow that would have occurred without dams and irrigation.
"Observed flow" is measured by USGS

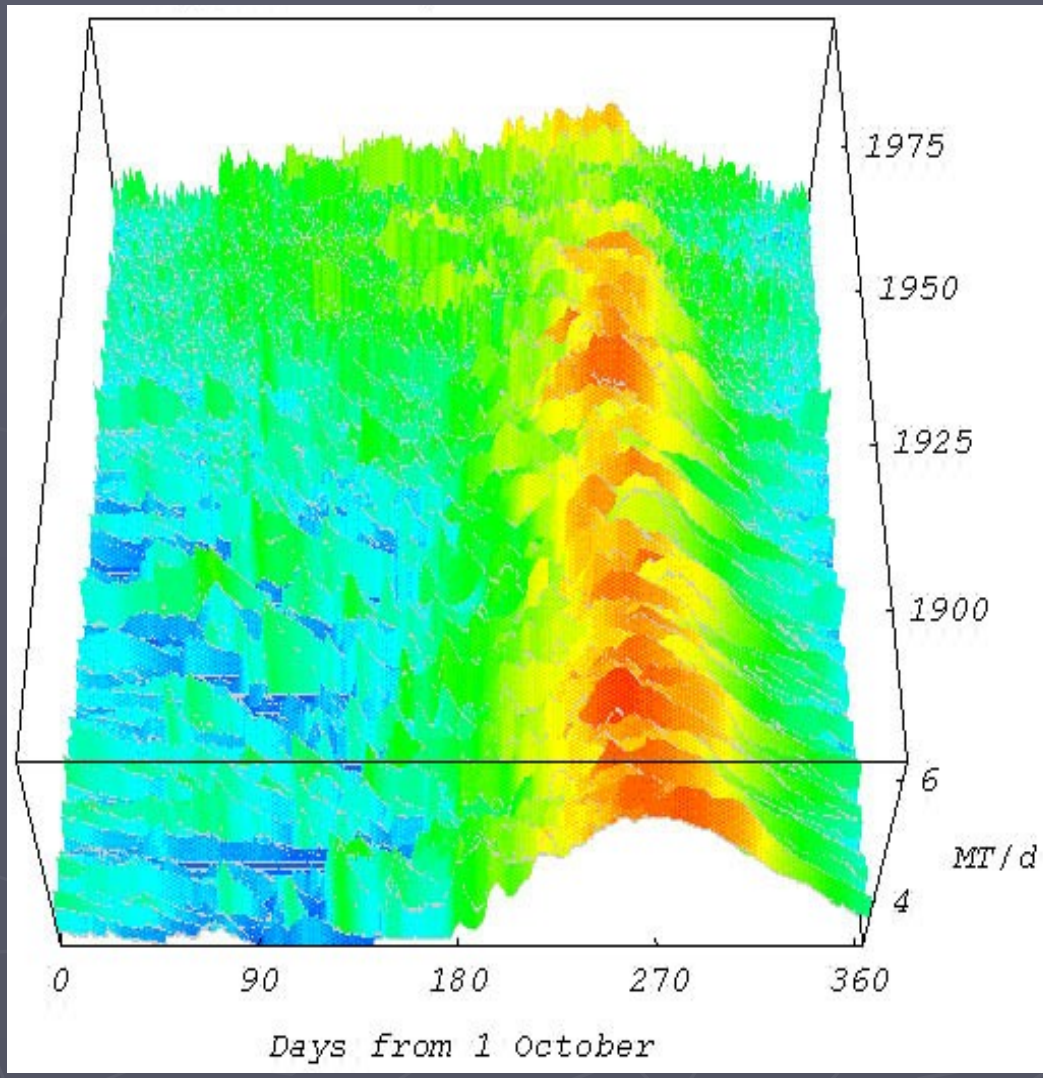




Changes in CR Hydrology:

Sediment Input

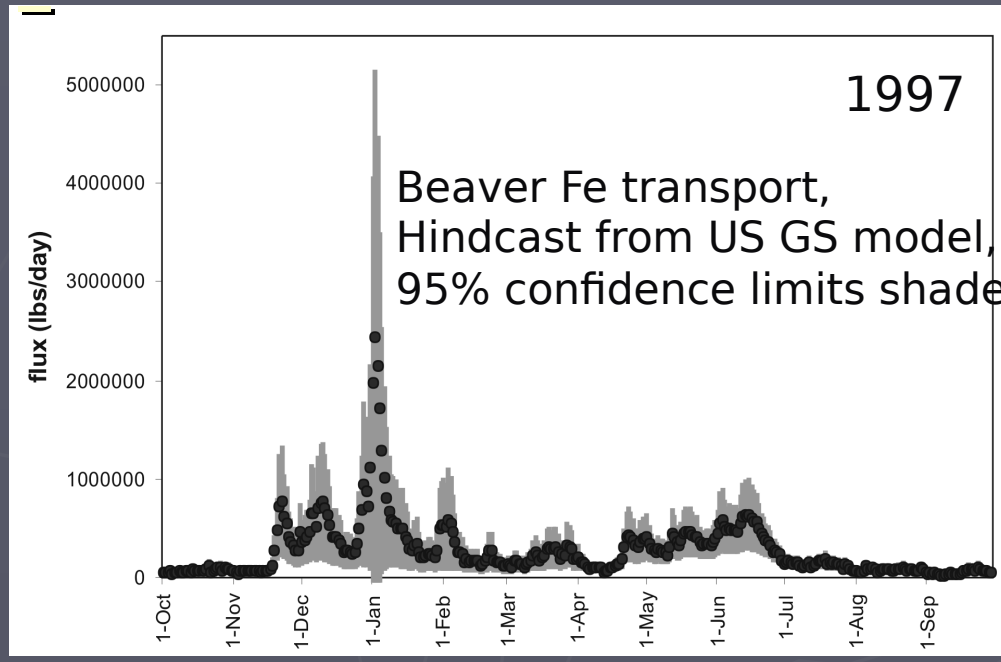
- Total load to estuary is down ~50% from <1900
- Sand input to estuary down >60%
- Much more sediment transport now occurs in winter
- Changes in turbidity in spring affects predation on and feeding by salmonids
- Fine sediment transports micronutrient iron to the plume. Changes may affect coastal primary productivity
- Sand delivery affects estuarine habitats and coastal stability

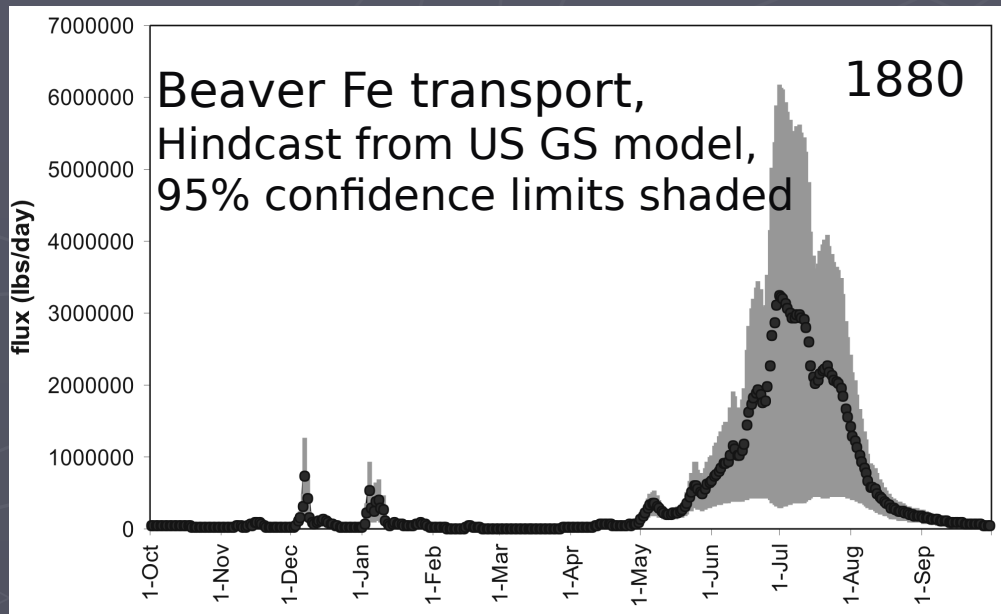


Log10 Total Load at Vancouver for Observed flow, 1878-1999

Changes in CR Hydrology:
Dissolved Iron (dFe) Input –

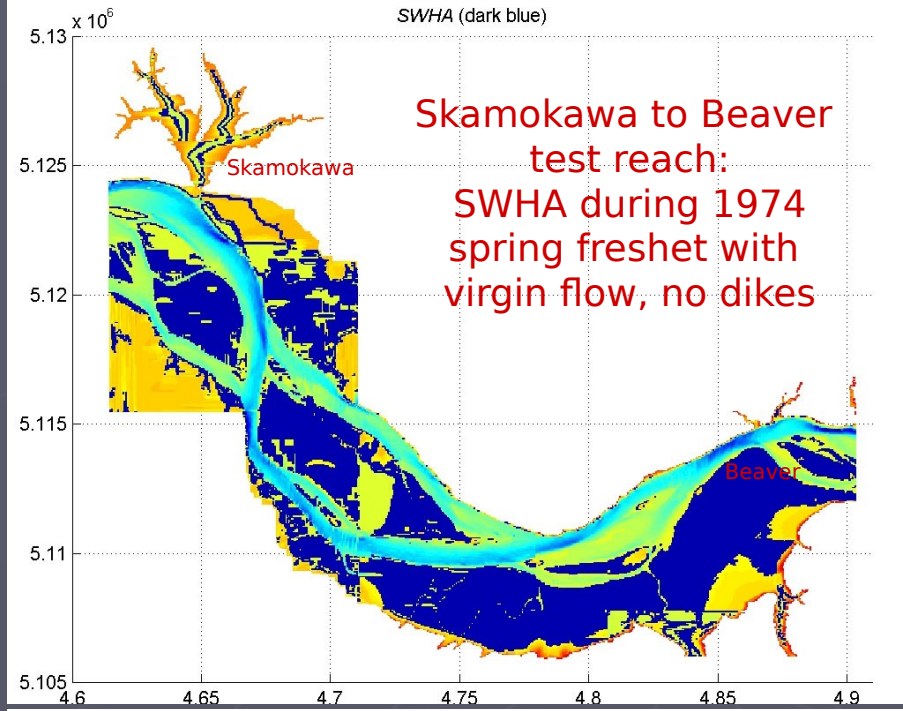
- dFe is a micronutrient for coastal productivity
- CR is a Mississippi-sized source of dFe
- USGS dFe models show:
  - Annual dFe input has decreased greatly
  - Modern dFe input is mostly in winter
  - Historic dFe input was mostly in spring
- Interactions of dFe with floodplain and estuary greatly changed

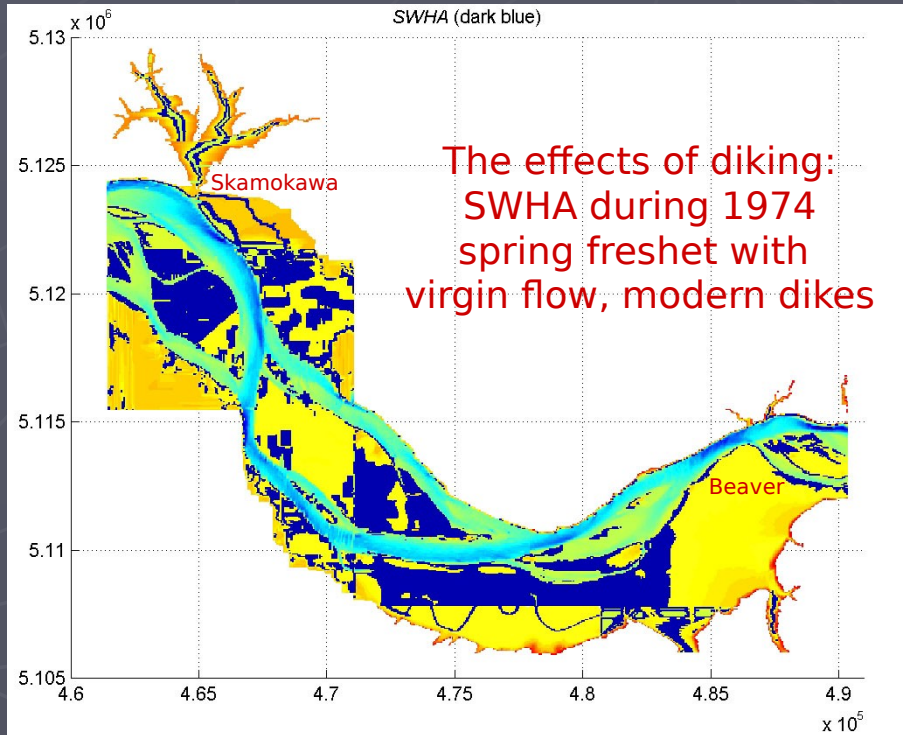




Changes in Shallow-Water Habitat Area (SWHA) –

- Juvenile salmonids use SWHA for shelter, feeding, growth
- SWHA is area where water is 0.1 to 2 m deep, given ambient river flow and tides
- Changes in SWHA indicate changes in ability of system to support juvenile salmonids
- River flow and tides interact in a complex way
- Use historic tidal, flow and geometry data to construct simple dynamic models

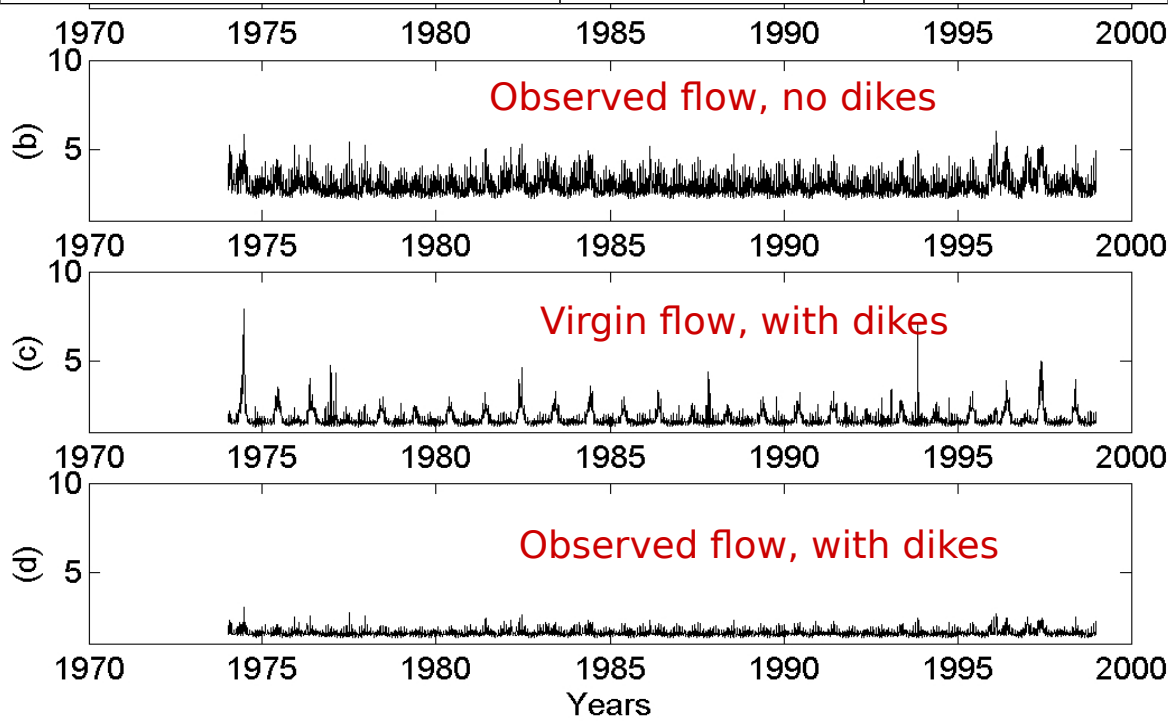




Changes in SWHA, 1974 to 1998 –

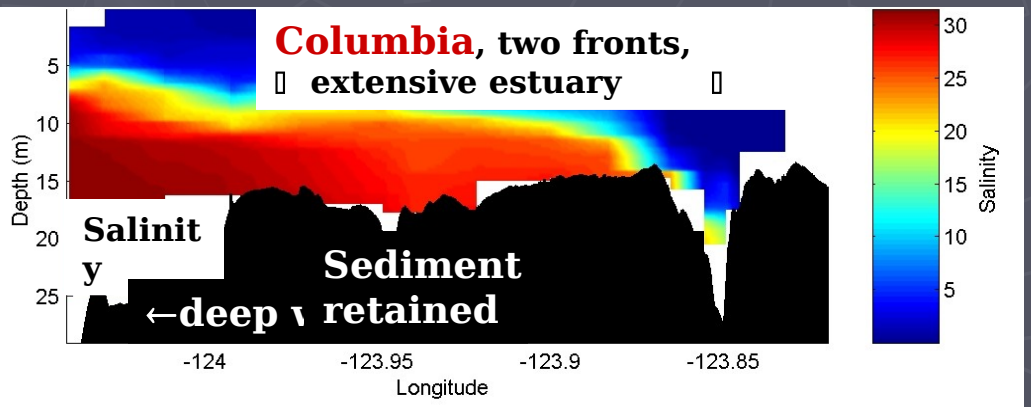
- Area AND duration of SWHA have decreased
- Dikes account for more loss of habitat than loss of flow
- Restoration projects must take into account the lower river stage
- River flow damps tides; remaining habitat is more strongly tidal
- Simple models allow analysis of changes over long periods!
- Supplement with numerical models for details

1974 to 1998 Average SWHA, 10^7 m^2	Freshet Season (May to July)	Rest of Year (Aug. to April)
a) Virgin flow, no dikes	4.5	3.0
b) Observed flow, no dikes	3.2	2.9
c) Virgin flow wi dikes		1.6
d) Observed flow, with dikes	1.7	1.6

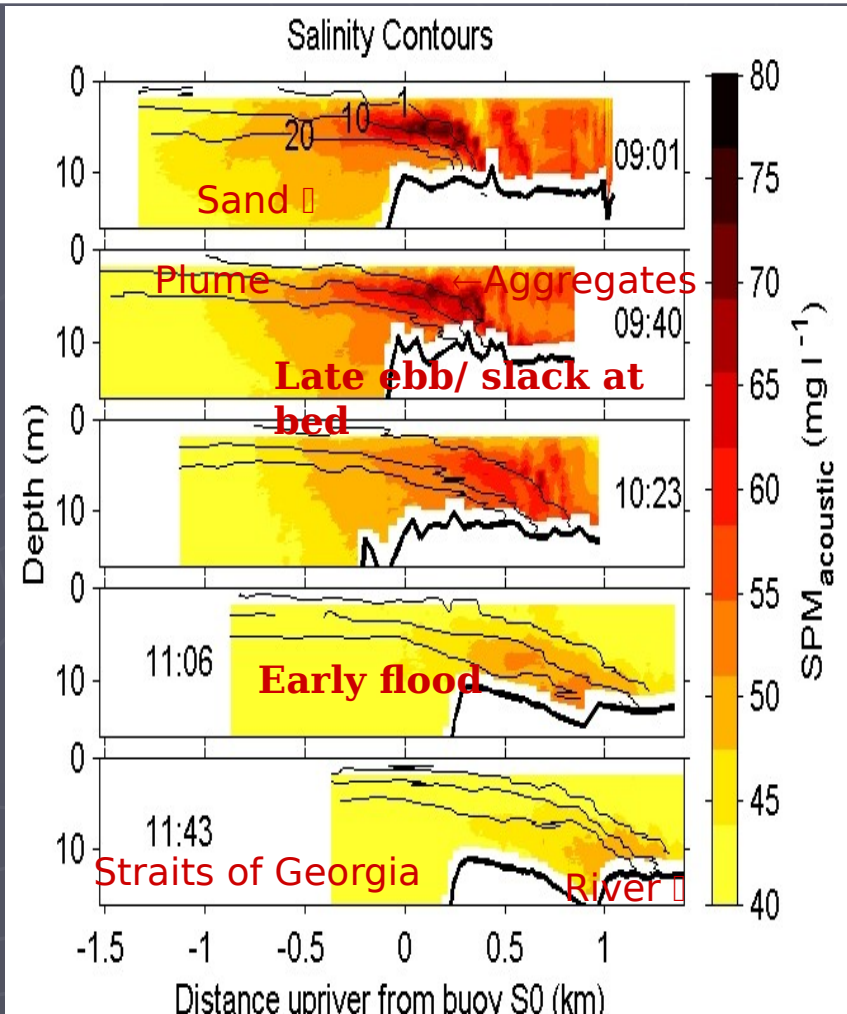


Estuarine Salinity Intrusion and Sediment Export:

- Fraser is the CR on steroids, like CR before flow regulation.
- Sand exported when salinity is forced back to Fraser River mouth on ebb
- Sand export no longer occurs in CR b cause of dredging, flow regulation
- “Zero-length estuary” vital for salmon habitat, geochemistry

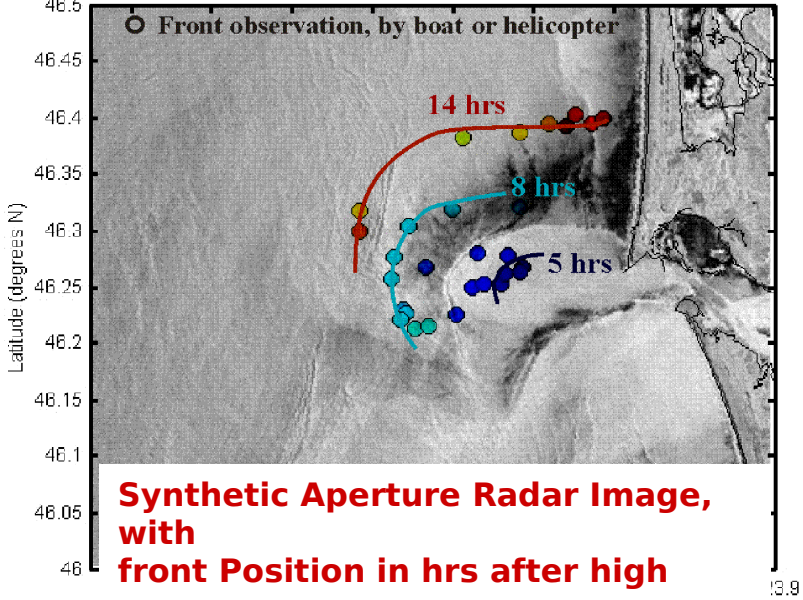


Sediment Export Event in the Fraser River (zero-length estuary)

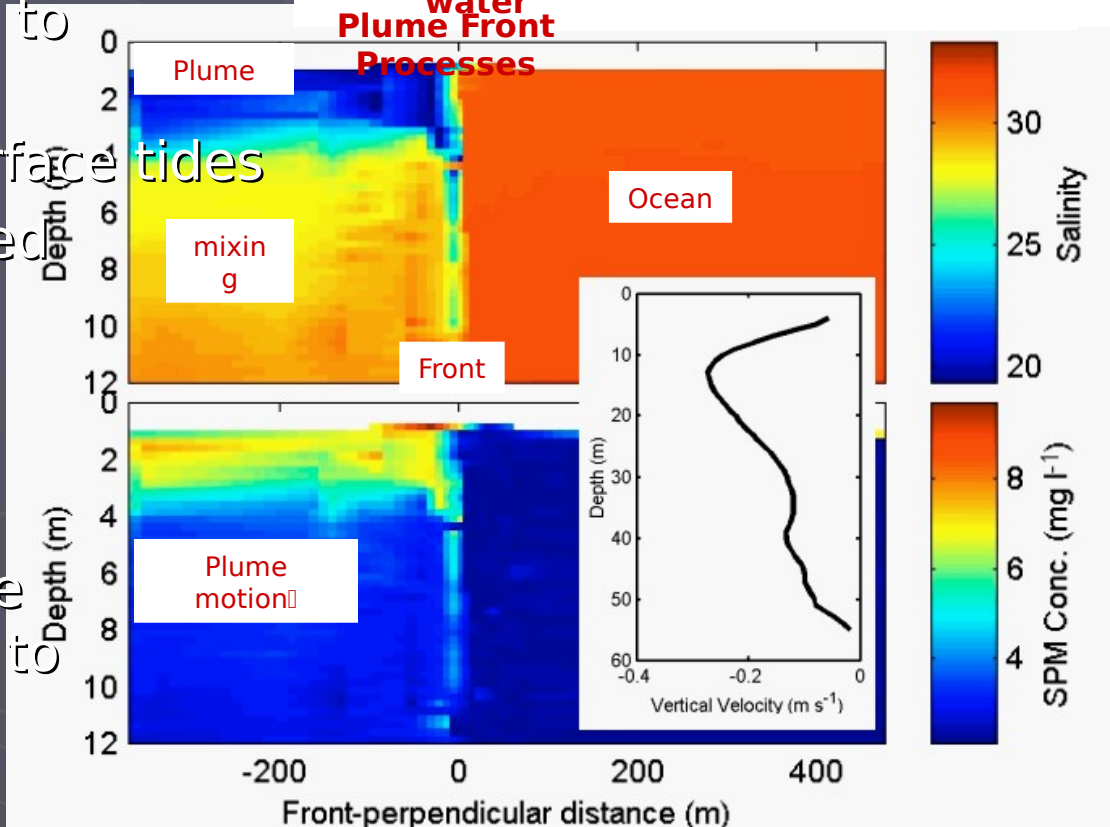


Plume Mixing and Fron

- Plume is vital for juvenile salmonids.
- Plume is highly mobile: winds, tides, flow
- Mixing occurs at fronts and in interior due to plume motion, winds, and internal tides
- N mixed into plume crucial to productivity
- Internal tidal currents >surface tides
- Flow regulation has changed plume habitat
- Climate change constrains future options
- If we think big, there ARE options – e.g., restoring dFe input may be a cheap way to improve productivity



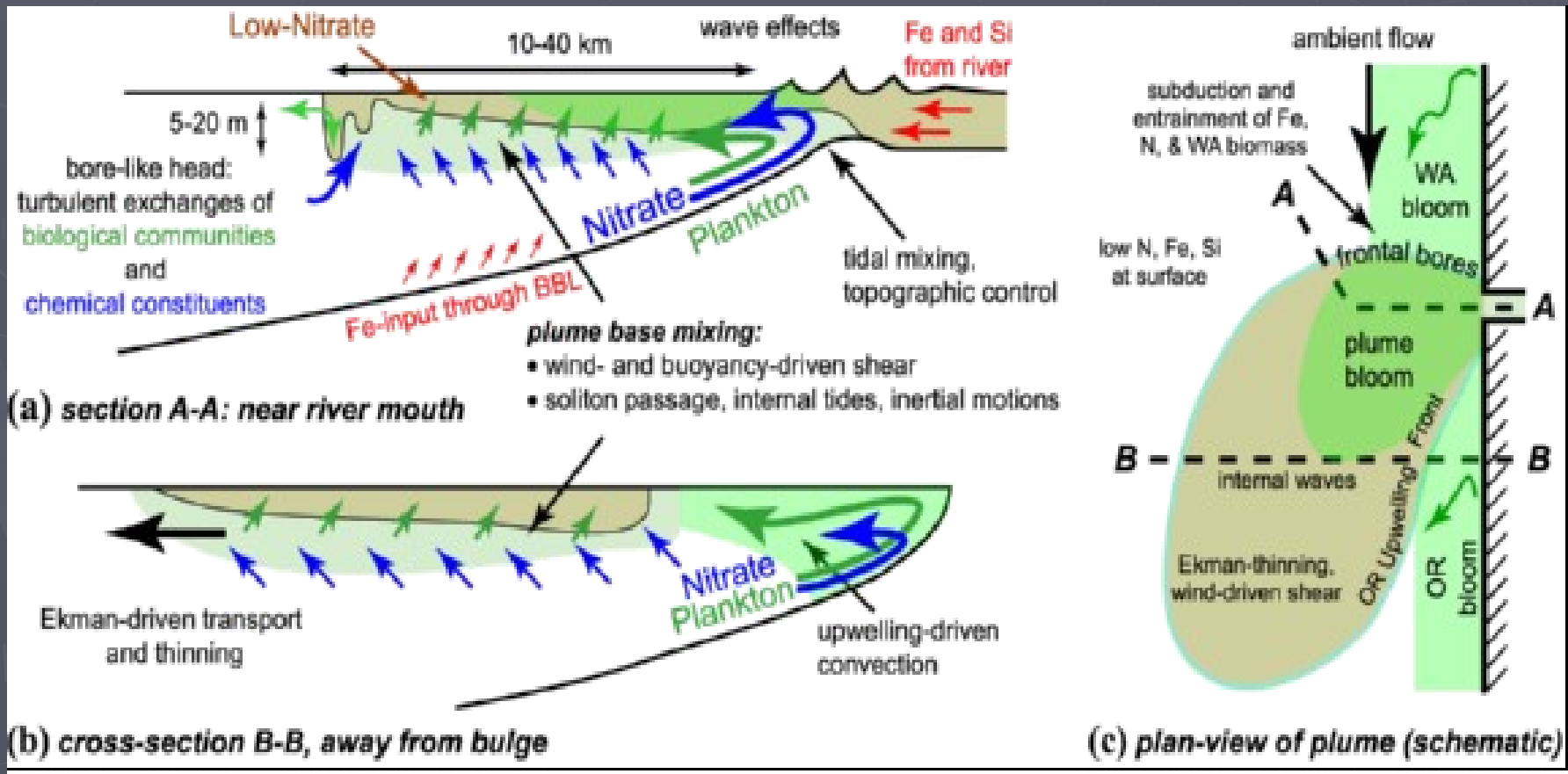
Synthetic Aperture Radar Image, with front Position in hrs after high water



Salinity and turbidity across a CR plume front:

River-Influenced Shelf Ecosystems (RISE) –

- RISE Project is NSF-funded 2003-07, will study plume primary production
- WA coastal productivity higher, because of winter or spring Fe input?
- How does plume influence shelf productivity?
- Is winter particulate Fe more important than spring dFe?
- RISE provides a basis for applied research to optimize hydropower impacts



What Problems Need to be Solved? How do we Solve Them?

- Columbia River Basin
- Tidal River and Estuary
- Columbia River Plume

Three distinct domains that need to be
studied in an integrated manner!

The Columbia River Basin –

The Basin: Hydrology and Sediment Supply (What?) –

- Basin hydrology – continue analyses of historical changes and future climate impacts; link to estuary and plume studies
- Sediment supply and export to ocean –
  - CR unique for a large North American river: we know so little about sediment supply and human impacts on it
  - Where are fines and sand coming from?
  - How has sediment budget responded to climate change, forestry, agriculture and flow regulation?
  - How has reduced sediment supply impacted estuarine habitats and littoral processes?
  - Where is the “lost” material being trapped/stored?
  - How has export to ocean been changed by dredging, changes in flow?

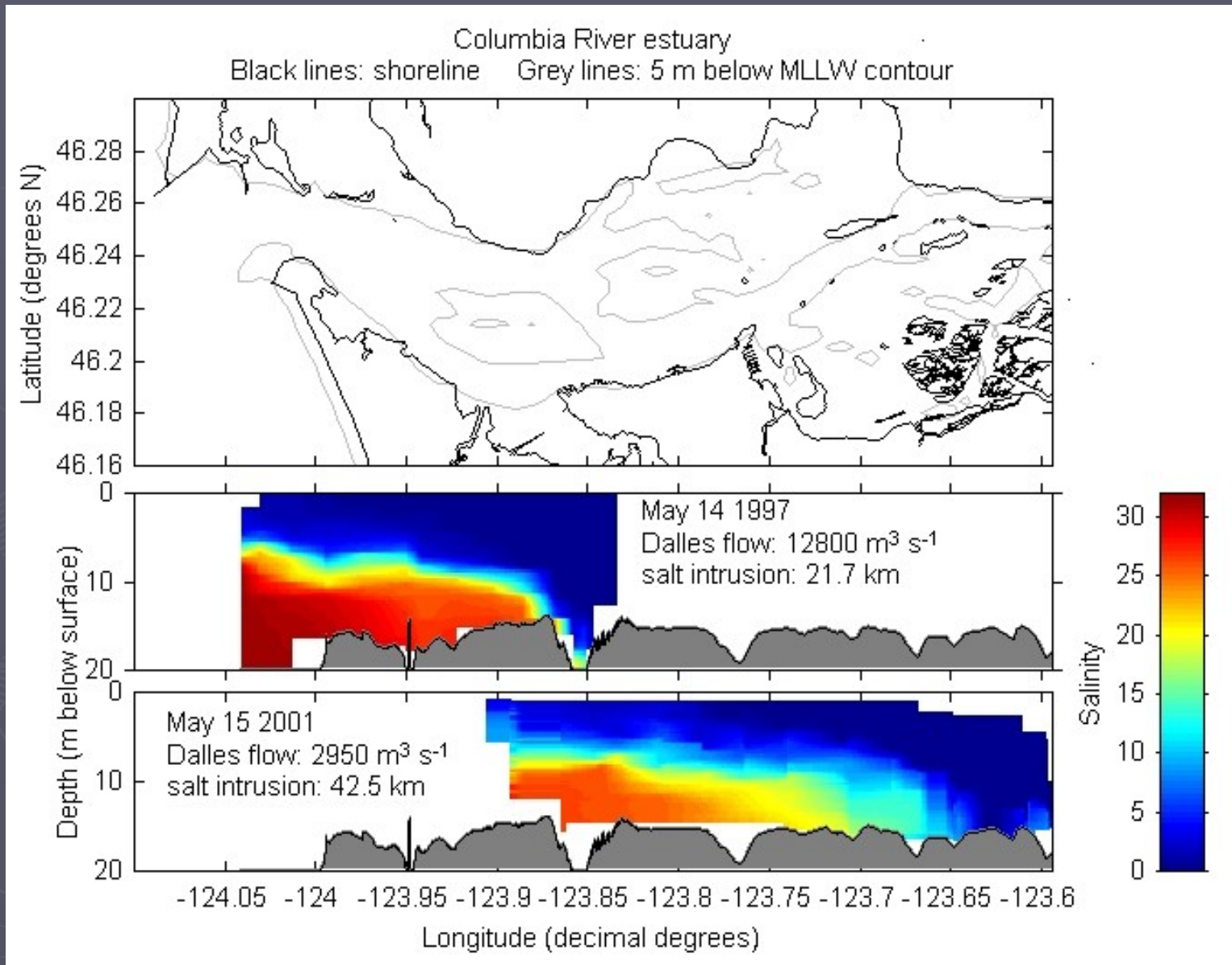
Hydrology and Sediment Supply (How?) –

- Important steps:
  - Resume monitoring sediment transport/character throughout the basin, using modern technology
  - Monitor bed sediment and bathymetric change
  - Make process measurements in river and estuary, to understand sand transport, connections to ecosystem
  - Model sediment transport in river, estuary and coastal ocean (connect to community sediment transport modeling)
  - Model basin hydrology to understand altered sediment supply
- Understand/manage sediment in the entire system as a unified whole, from basin to coastal littoral cell!
- Sediment and turbidity are vital resources!

Geochemistry (what?) –

- Vital to understanding changes in system productivity!
- Nutrient chemistry –
  - How has nutrient supply to estuary changed?
  - Estuary vs. reservoirs – is the Columbia the rare estuary with decreased nutrient supply?
  - Importance of groundwater to nutrients and toxics
- Iron supply and dynamics –
  - Where does Fe supply come from? (mostly from volcanics)
  - How have particulate Fe, dFe changed due to reservoirs?
  - How did loss of floodplain affect Fe dynamics?
  - Importance of zero-length estuary!
- How does the organic material supplied to the estuary change with flow and season?
- How have organics supplied to estuary changed with flow regulation and diking/elimination of flood plain?

The Tidal River and Estuary –



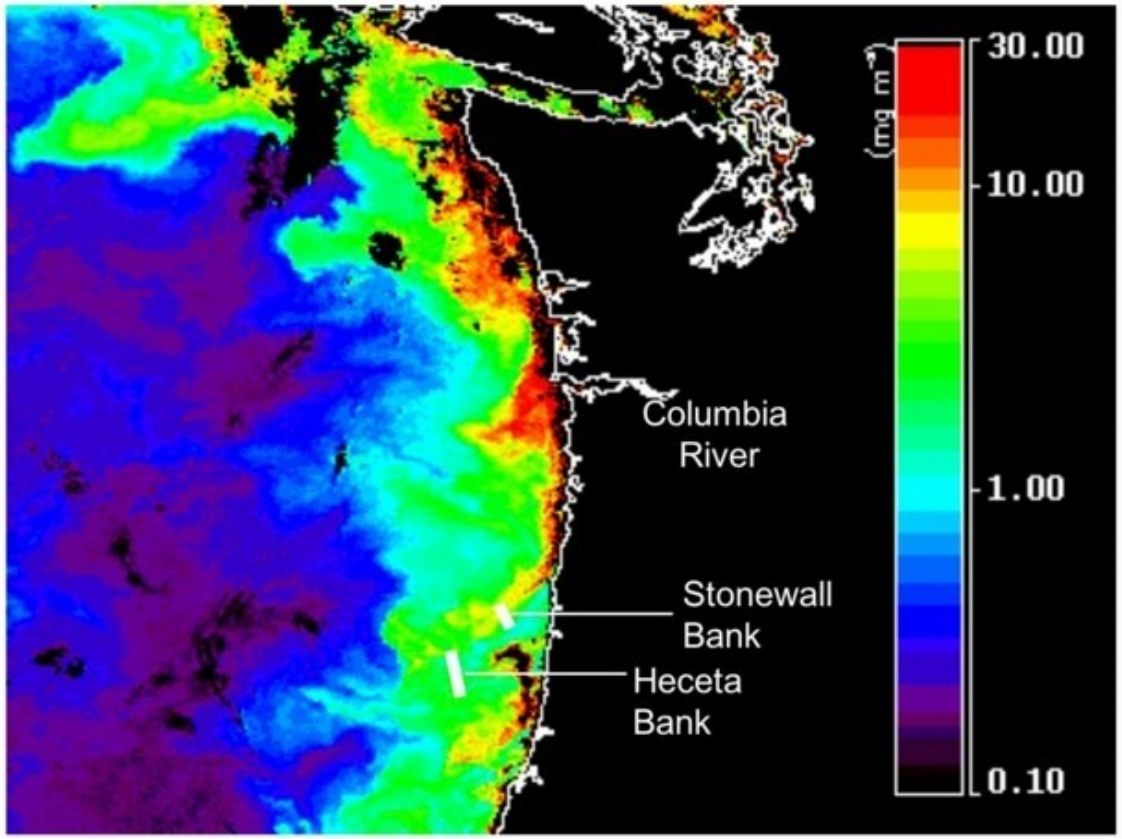
In the Tidal River and Estuary –

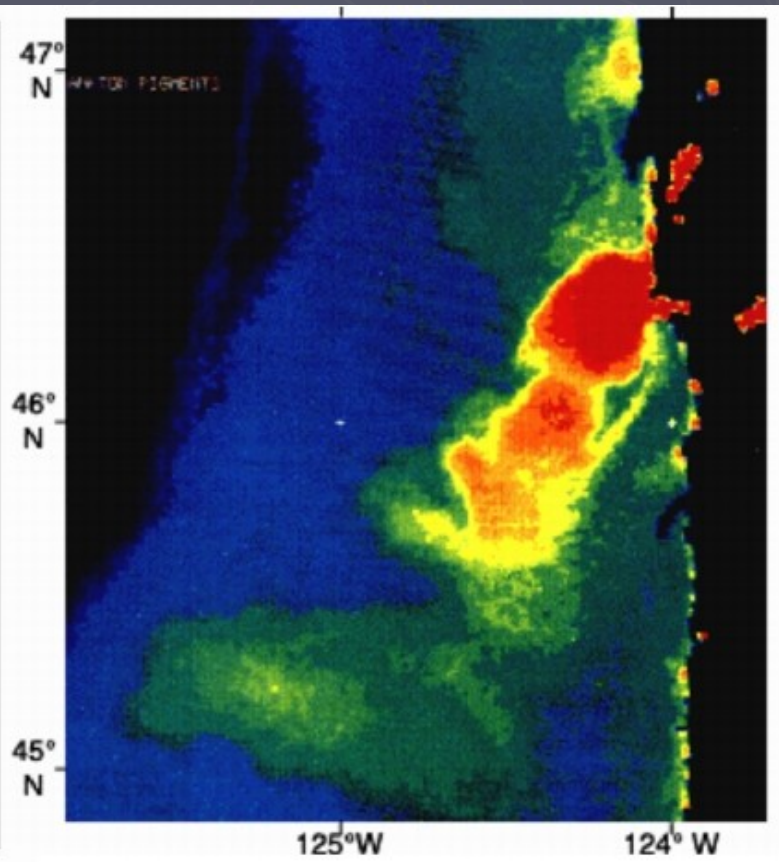
- Need to support habitat restoration, flow management, navigational use
- Gaps are defined (we mostly know what we don't know) –
  - Topography and changes in topography
  - Bed material and changes in bed material
  - Historical changes in tidal regime
  - Historical changes in the salinity regime and vertical mixing
  - Historical changes in the turbidity maximum
  - Changes in the sediment budget – sand and fines are both important
  - Changes in processing of nutrients, micronutrients and organic matter
  - How has the ecosystem in the turbidity maximum changed?
- How do these alterations and climate change constrain management of navigation, flow management and habitat restoration?

Plume and Coastal Ocean

Left: SeaWiFS 26 June 2000, Chl, mg m^{-3}
Note high Chl off WA

Right: CZ Color Scanner, from 24 May 1982
Note large plume area





In the Plume and Coastal Ocean –

- Plume is vital to juvenile salmon
- Plume is affected by changes both in basin AND in NE Pacific!
- Gaps ill defined (DON'T fully know what we should ask)
- Some questions –
  - What is the role of fluvial nutrients and micronutrients in plume and coastal productivity? (the RISE Project)
  - How are upwelled nutrients mixed into plume-area surface waters by tides/internal tides and wind mixing? (RISE)
  - How have flow management and climate change altered:
    - coastal primary and secondary productivity? (BPA - NOAA plume project)
    - plume circulation, turbidity and plume salmon habitat? (plume projects)
  - How do juvenile salmon respond to tides at entrance, turbidity in estuary/plume?
  - How will climate changes in basin and NE Pacific constrain future management decisions? (BPA - Optimization project)

Plume and Coastal Ocean (Continued) –

- How can we move from studies to management?
  - Understand better how system is managed (BPA - *Optimization*):
    - How are flow management decisions made in good vs. bad years?
    - How can science be most easily be made available to managers?
    - How do management practices conflict with a system approach to understanding and management?
  - Improve communication between scientists and managers
  - Use process knowledge to define flow scenarios that maximize estuary/plume salmonid habitat
  - Evaluate scenarios through remote sensing and numerical models (BPA-NOAA Plume project)
  - Need to involve PNW coastal ocean researchers in CR plume management issues!
  - Learn from mgt of other systems, e.g., the Colorado

Summary –

- CR basin, river estuary and coastal ocean function as a system
- CR system needs to be understood in an integrated way
- An organized effort should be made to define and answer system-level questions
- Need to involve a broader group of PNW scientists, learn from science/management of other systems
- Need to modify management practices that interfere with understanding and management of system in an integrated manner